DESIGN FOR THE STRUCTURAL SURFACE MATERIAL ENABLING SHIELDING FOR INTERFERENCE MITIGATION WITHIN THE BUILDINGS IN THE UNLICENSED 2.4GHZ ISM BAND

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Abstract

This work is proposed to design shielding for interference mitigation and network security within the buildings in the unlicensed 2.4GHz ISM band and to provide maximum transparency at broadcast frequencies. Thus, mobile phones, radio and television signals in buildings will not be affected. Frequency Selective Surface (FSS) is attached onto existing common construction material to transform the standard material into a band stop frequency selective wall. To obtain the band response of FSS having a desired frequency interval, a new FSS periodic element geometry is introduced. The obtained results show that desired frequency response is achieved. HFSS software is used for simulation purposes.

Keywords: Frequency selective surface, FSS, Periodic Structures, Wireless Communication, Wireless Local Area Network (WLAN), Indoor propagation, interference.

1. Introduction

There is a growing need to control the propagation of electromagnetic waves within buildings in recent years [1]. The wireless devices in the unlicensed ISM bands cause mutual interference in indoor environments. This interference not only degrades system performance but also compromises security. Interference mitigation can be achieved using advanced signal processing or antenna designs. A more and an efficient approach is to transform a building wall to a frequency selective surface which filters out undesired signals but allows the others [2]. Frequency selective surfaces (FSS) are periodic structures which have filter characteristics depending upon their geometries when interacting with electromagnetic waves [3,4]. They have been used in many applications such as radomes, dichroic sub-reflectors, photonic band gap structures and artificial magnetic conductors. Recent uses of FSSs include military applications, antennas, telecommunications and wireless security [3,4].

This work is proposed to design a shielding for interference mitigation and network security within the buildings in the unlicensed 2.4GHz ISM band. An attenuation of 10dB on the transmission (21) parameter is desired for 2.4GHz ISM band while providing maximum transparency at broadcast frequencies [5]. For classical FSS designs, 2.4GHz ISM band is a relatively low frequency band and has a narrower bandwidth. There are several element geometries used in FSS designs and among them "Four Legged Loaded" FSS element geometry is selected to achieve a narrow band frequency response [3]. This element has two geometric parameters that control the bandwidth. But, in our design the obtained results show that the band characteristic does not satisfy the required bandwidth. Therefore a new FSS periodic element geometry which is consisted of two different sized "Four Legged Loaded" is introduced. For the new designed element geometry a narrow bandwidth of 130MHz is obtained for 10dB attenuation at 2.4GHz at the expense of a second resonance frequency at 4.4GHz. Due to the frequency range between 4GHz and 5GHz is not used for indoor wireless communication systems, the second resonance frequency at 4.4GHz does not affect the performance of our design. Further to that these results give us the opportunity to design FSS which has two (or more) resonance frequency.

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2. Modeling of FSS

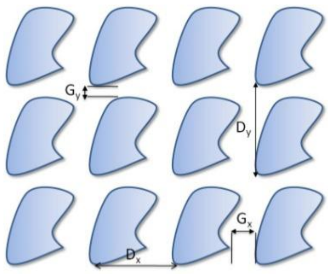

Figure 1. Frequency selective surface

One of the most important factors influencing the response of FSS is the element geometry, element size (D_x, D_y) and the gaps (G_x, G_y) between the elements as shown in Figure 1. Element size should be small in terms of wavelength to avoid grating lobes [2,3]. For such a loop type element geometry as shown in Figure 2, the element sizes are typically less than about 0.3 wavelength. This kind of element geometry gives us the opportunity to obtain a desired bandwidth in a wide range [3]. Therefore "Four Legged Loaded" element geometry is selected as the initial geometry four our design.

Dielectric surfaces on which FSSs are placed, change the frequency response of the structure [6]. Therefore conventional building materials on which FSS is deployed will affect the frequency characteristics of FSS. It has been reported in the literature that with sufficient spacing between a wall and its FSS cover the mutual influence can be neglected [7]. The results give us the opportunity to design FSS without considering building materials' properties.

3. Proposed Structure Design

The basic "Four Legged Loaded" element geometry is used for FSS design and its transmission (s21) and reflection (s11) curves are shown in Figure 2 and Figure 3 respectively. To obtain the frequency response HFSS software is used. Such geometry has the advantages of simple in structure, easy fabrication, polarization insensitivity and adjustable frequency bandwidth.

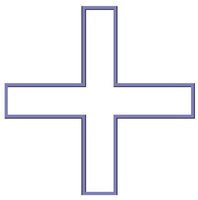

Figure 2. "Four Legged Loaded" periodic element geometry

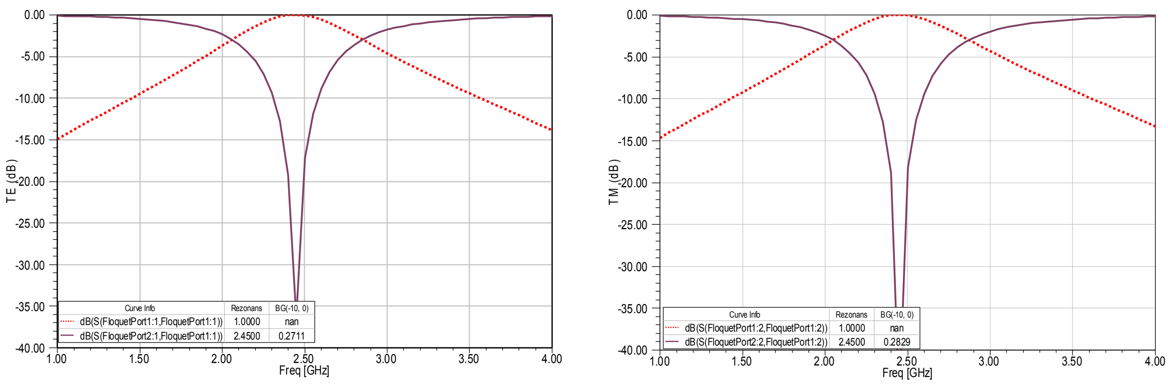

Figure 3. s21 and s11 frequency curves (TE and TM polarization)

As shown in Figure 3 the transmission band is not able to satisfy the required bandwidth. To achieve a narrower band frequency response, two different sized "Four Legged Loaded" element geometry is used as shown in Figure 4. Given results in Figure 5 and Figure 6 show that the obtained bandwidth is half of the bandwidth of simple "Four Legged Loaded" element bandwidth.

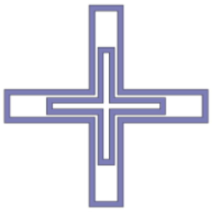

Figure 4. A pair of different sized "Four Legged Loaded" periodic element geometry

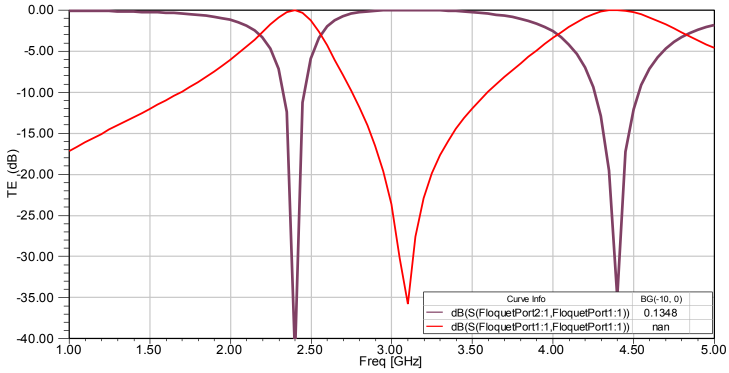

Figure 5. s21 and s11 frequency curves (TE polarization)

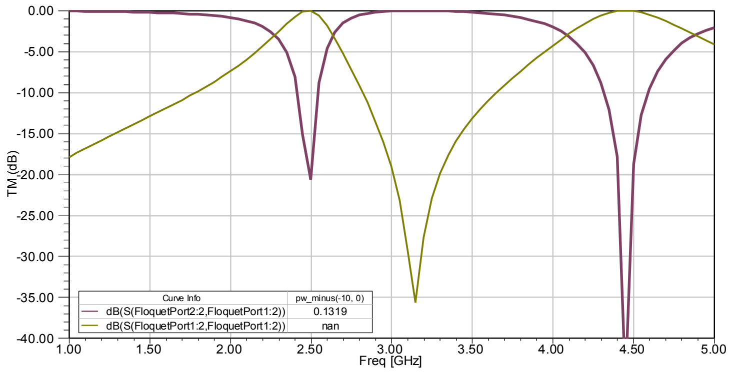

Figure 6. s21 and s11 frequency curves (TM polarization)

In general, the performance of FSS structures depends on incident of the illuminating wave. For narrowband wireless applications, it is expected that FSS exhibits stable resonance frequency in different incidence angles. In Figure 7 and Figure 8 oblique incidence performances of frequency selective surfaces are investigated. The FSS has a good frequency stability for both TE and TM polarized waves not only for the normal incident angle but also for oblique incidence angles ranging from 0–60 degrees. As shown in Figure 7 and Figure 8, resonance frequencies of TE polarization are at 2.4GHz and resonance frequencies of TM polarization are between 2.45GHz and 2.5GHz for all oblique incidence angles.

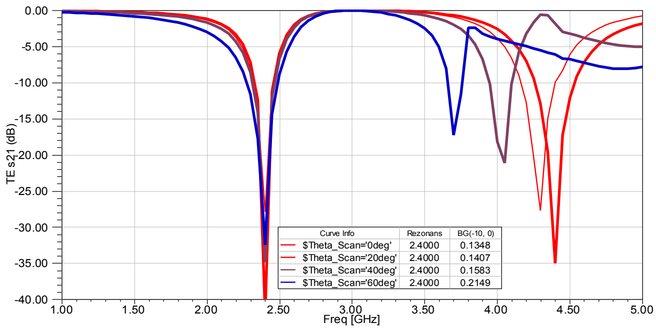

Figure 7. s21 and s11 frequency curves (TE polarization and oblique incidence)

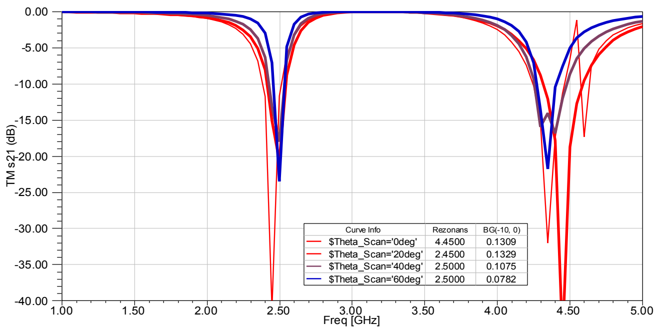

Figure 8. s21 and s11 frequency curves (TM polarization and oblique incidence)

4. Conclusion

In this work a band stop frequency selective surface is designed for interference mitigation and network security within the buildings in the unlicensed 2.4GHz ISM band. A new element geometry is introduced to achieve a narrower bandwidth at the resonance frequency. Although satisfying bandwidth of 130MHz is obtained for 10dB attenuation at 2.4GHz, this periodic element geometry has a second resonance frequency at 4.4GHz. The frequency range between 4GHz and 5GHz is not used for indoor wireless communication systems. Therefore, this design can be used for interference mitigation and network security in indoor wireless environment. Besides, this FSS element geometry design can be used to obtain a transmission characteristic which has two different pass bands.

5. Acknowledgments

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6. References

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